Semi-Annual Progress Report

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Task Objectives

The objectives of the last six months were:

- Evaluate the Version 2 algorithms for Fluorescence Line Height and Chlorophyll Fluorescence Efficiency
- Revise the Algorithm Theoretical Basis Document (ATBD) and participate in panel review
- Deploy bio-optical instrumentation at the Hawaii Ocean Time-series (HOT) site as part of the Joint Global Ocean Flux Study (JGOFS)
- Deploy bio-optical drifters in the Polar Front as part of JGOFS Antarctic Environment Southern Ocean Process study (AESOPS)
- Submit manuscript on bio-optical time scales as estimated from Lagrangian drifters
- Conduct chemostat experiments on fluorescence
- Continue development of advanced data system browser
- Continue to review plans for EOSDIS and assist ECS contractor.

Work Accomplished

Delivery of CFE and FLH Code

We are responsible for the delivery of two at-launch products for AM-1: Fluorescence line height (FLH) and chlorophyll fluorescence efficiency (CFE). In our last report we had planned to combine the two separate algorithms into a single piece of code. However, after discussions with Bob Evans (Univ. Miami), it was decided that it was best to leave the two algorithms separate. They have been integrated into the MOCEAN processing system, and given their low computational requirements, it easier to keep them separate. In addition, there remain questions concerning the specific chlorophyll product that will be used for the CFE calculation. Presently, the CFE algorithm relies on the chlorophyll product produced by Ken Carder (Univ. South Florida). This product is based on a reflectance model, and is theoretically different than the chlorophyll product being provided by Dennis Clark (NOAA). These two products will be compared systematically in the coming months. If we decide to switch to the Clark product, then it will be simpler to modify the CFE algorithm if it remains separate from the FLH algorithm.

Our focus for the next six months is to refine the quality flags that were delivered as part of the algorithm last summer. A description of these flags was provided to Evans for the MOCEAN processing system. A summary was included in the revised ATBD. Some of the flags depend on flags produced by the input products (e.g., the Carder absorbed photons product, the Gordon water-leaving radiances, etc.) so coordination will be required.

ATBD Revision

A completely revised version of our Algorithm Theoretical Basis Document (ATBD) was delivered to the EOS Project Science Office in September. The revised ATBD contains a complete sensitivity study of the FLH algorithm which has just appeared in *Remote Sensing of the Environment* (Letelier, R.M., and M.R.

Abbott, “An analysis of chlorophyll fluorescence algorithms for the Moderate Resolution Imaging Spectrometer (MODIS),” Remote Sens. Environ., 58, 215-223, 1996). The ATBD also describes our approach to the estimation of the quantum yield of fluorescence which will form the basis of future physiologically-based productivity models.

We presented the revised ATBD and our response to the one external review at NASA Headquarters in early December. We were unable to attend the full review in November due to prior travel commitments. The only negative comment from the mail reviewer concerned our use of a straight baseline instead of a curved baseline for the FLH calculation. We noted that the uncertainties in the curved baseline approach were far larger than the straight baseline, and that we saw no particular value in introducing more uncertainty into the FLH process.

Algorithm Validation Activities

We are taking two approaches in our validation work for FLH and CFE. First, we are measuring sun-stimulated phytoplankton fluorescence in a wide variety of oceanographic conditions which will provide quantitative limits on the variability of FLH and CFE and the relationship of this variability to environmental and physiological factors. The most significant challenge in FLH and CFE will be its interpretation in the context of phytoplankton physiology. Second, we are quantifying the time and space scales of variability of fluorescence and productivity. These estimates will be used to develop quality assurance tests as well as to develop rigorous tests for product validation.

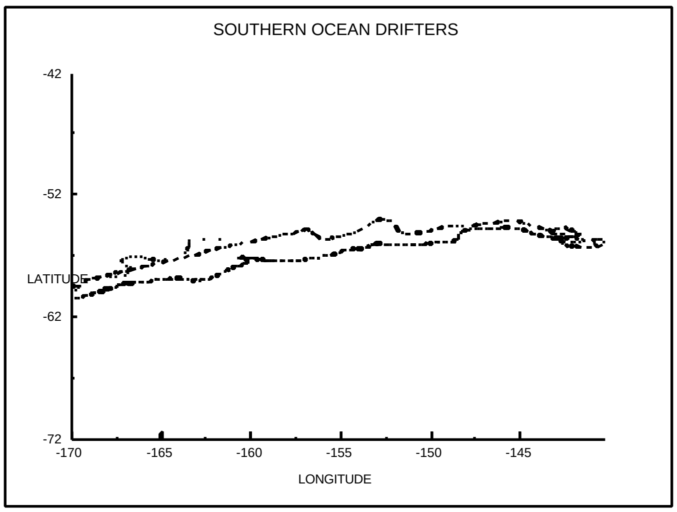
We are leveraging field opportunities to keep costs manageable. This past summer, we participated in a survey of the productive nearshore waters off the Olympic Peninsula in Washington. Surveys of chlorophyll, nutrients, productivity, and bio-optics were conducted within 10 km of the coast, a region of the ocean that is only occasionally sampled. The science focus was on the coupling between the shoreline ecosystem and the coastal ocean. We used a Tethered Spectroradiometer Buoy to collect water-leaving measurements close to the coast. These were compared with extracted chlorophyll from water samples. The relationship the bio-optical measurements and chlorophyll was quite good. We did not collect a sufficient number of samples to draw any conclusions on fluorescence, but we are proposing to NSF to make long time series measurements of optical properties in this region.

A longer term opportunity is presented by the U.S. JGOFS time series station in Hawaii (the Hawaii Ocean Time-series or HOT site). We have deployed a bio-optical sensor at the JGOFS Hawaii Ocean Time-Series station north of Oahu. The sensor package will be recovered in May 1997. We have also ordered the components necessary to assemble a second bio-optical sensor. This will allow us to service one unit and deploy the other unit. The HOT research team plans to maintain this mooring for the next several years. Given that it is visited monthly, this means we will have a full suite of biogeochemical observations to complement the bio-optical data. Last summer, we also participated in a cruise from HOT to the CLIMAX station, another long-term observing site in the central oligotrophic gyre of the Pacific. These data revealed the presence of a large subsurface phytoplankton bloom that had an optical signal characteristic of phycoerythrin-containing organisms. Initially, we thought that this bloom was composed of nitrogen-fixing cyanobacteria but microscopic analysis revealed that the bloom was composed mostly of diatoms. It appears likely that these diatoms have a symbiotic relationship with cyanobacteria which would result in the observed bio-optical signal.

Although such partnerships are an excellent way to improve scientific return and to reduce costs, one of the downsides is the inability to control schedules and activities. We had our bio-optical mooring equipment ready for deployment since the beginning of 1996, but we had to repeatedly delay because of ship scheduling and personnel issues that were out of our control. However, in the long run, such delays are minor compared with the eventual return.

Our second approach is to provide quantitative estimates of the scales of bio-optical variability, especially in the area of fluorescence. As reported earlier, there are significant differences onshore and offshore, reflecting changes in the scales of the physical environment. Two papers on these results are in press, and a third is in preparation. We have included one (a manuscript that will be published in SPIE Ocean Optics XIII) in the appendix.

Bio-optical drifters were deployed in the U.S. JGOFS program in the Southern Ocean known as AESOPS (Antarctic Environment Southern Ocean Process Study). Part of AESOPS will focus on mesoscale variability in the Antarctic Polar Frontal Zone and its role in governing biogeochemical fluxes. The bio-optical and conventional drifters are equipped with GPS units to provide estimates of near-surface convergences and divergences associated with frontal meanders. These properties will be compared with an array of moored bio-optical sensors and high-resolution SeaSoar surveys of the biological and physical environment. These activities will largely be funded by the National Science Foundation, but MODIS funding has been used to acquire six bio-optical drifters to continue our algorithm validation activities at the high latitude Polar Front. Three of these drifters were deployed this September at the Polar Front. The drifter tracks are shown below. Note the strong meandering associated with the Polar Front. Unfortunately, one of the drifters failed early because of a defective battery pack, and another had high noise levels because of a bad wiring connection. METOCEAN Data Systems will provide a replacement drifter for deployment later this year. We are continuing to analyze the optical data from the drifters. The remaining three will be deployed this year in the main AESOPS field season. The FRR fluorometer will also be used during the next field season for assessments of the relationship between photosynthesis and fluorescence.



Algorithm Development

We have included a copy of a manuscript that is in press in *Geophysical Research Letters*. This paper documents the changes in FLH which can be used to estimate an apparent quantum yield of fluorescence. Variations in apparent quantum yield appear to be driven by changes in the nutrient regime, and this information could be used to improve models of primary productivity. Our approach is based on using this quantum yield to estimate P_{max}, which characterizes maximum photosynthesis in photosynthesis/irradiance experiments. P_{max} is critical variable in the present generation of productivity models.

We have acquired all of the necessary components to begin the long-delayed chemostat experiments. We will study the effects of nutrient and light history on the quantum yield of fluorescence. This work will provide a solid basis for the productivity algorithm.

At the Fall MODIS team meeting, Howard Gordon reported that the effects of scattering from whitecaps might be severe, especially in algorithms such as FLH, based on model studies. However, his recent work shows that this is unlikely to be a serious problem except for winds greater than 12 m/s. These results are based on field measurements in which the impact of whitecaps is small until the winds become strong and the sea surface is dominated by breaking waves. In such cases, it should be relatively straightforward to flag these pixels.

GLI Activities

The Japanese space agency, NASDA, released a Research Announcement soliciting proposals for algorithm development for GLI. This sensor is similar to MODIS and will launch in mid-1999 on ADEOS-II. MOCEAN will provide NASDA with copies of the MODIS oceans algorithms that we submit to the MODIS SDST. We will compare the equivalent MODIS data products with those from GLI. We expect to receive copies of the GLI algorithms as well. We will also pursue techniques to blend these two data products together and participate in join validation and calibration activities to support data synthesis. Our plan has evolved to include the hiring of a full-time person at OSU to act as the “point person” for MODIS/GLI integration for the oceans data products. A search is presently underway for someone to take this position. We have several applicants, some of whom are outstanding.

EOSDIS Plans

We are continuing are work with Web browser interfaces to our data base of in situ bio-optical measurements and satellite imagery. We presently have 60 GB of data in our archive, and we are prepared to handle OCTS and SeaWiFS imagery when it becomes available. Our retrieval and analysis tools are based on Java and ActiveX from Microsoft. In addition to data overlays and plots of drifter tracks, we have also built animation tools which allow viewing of large numbers of images. These tools are used as distributed objects that execute either on the server or the client. We will demonstrate these systems to Hughes and GSFC personnel in January. Full technical reports are in production and will be included in the next semi-annual report. We will continue this activity in 1997 with Hughes and MODIS funding.

With the delays in the release of the EOSDIS Core System (ECS), we have spent considerable time with the ESDIS project and the MODIS Science Data Support Team in providing input on fallback plans and basic requirements for ECS. We expect this to continue over the next several months and ESDIS works to ensure that the basic ECS is functioning in time for AM-1 launch.

Anticipated Future Actions

- Retrieve bio-optical mooring in Hawaii and analyze fluorescence data
- Refine quality assurance plan and quality flags for our data products. Specific threshold values will be defined, based on input from other MODIS products.
- Begin chemostat experiments on the relationship of fluorescence quantum yield to environmental factors. Establish relationship between fluorescence quantum yield and photosynthetic parameters.
- Hire postdoctoral level person to serve as point of contact for MOCEAN and GLI activities. Deliver V1 code to GLI oceans team and begin to define integration issues.
- Continue to develop and expand browser-based information system for in situ bio-optical data.

Problems and Solutions

Although prelaunch characterization of MODIS is still an issue, the most important issue facing us is the delivery schedule of ECS. It has become difficult to develop and test code as schedules and capabilities change.

Appendix

Manuscripts in press related to MODIS research. The first manuscript is in press in *Geophysical Research Letters*; the second manuscript is in press in SPIE Ocean Optics XIII. Figures have not been included with the first manuscript.